# Cyclonic froth flotation cell

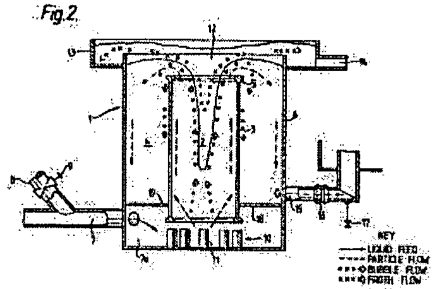
**Publication number:** GB2162092 (A)
**Publication date:** 1986-01-29
**Inventor(s):** CUTTING GEOFFREY WALTER
**Applicant(s):** TRADE & INDUSTRY SECRETARY OF
**Classification:**
**- international:** ***B03D1/14; B04C7/00;*** **B03D1/14; B04C7/00;** (IPC1-7): B03D1/24; B04C7/00
**- European:** B03D1/14C; B04C7/00
**Application number:** GB19850018103 19850718
**Priority number(s):** GB19840018725 19840723

**Also published as:**
GB2162092 (B)

Abstract of **GB 2162092 (A)**

A cyclonic froth flotation cell, suitable for use in the separation of minerals comprises concentric inner and outer cyclones (2, 4). A liquid feed containing particles and injected dissolved air is fed tangentially via a conduit (7) into an inlet chamber (7a) below the outer cyclone and in communication with the inner cyclone. On contact with a stator (10), bubbles are generated which form a froth with hydrophobic particles in the feed. The feed passes up through the inner cyclone (2) and the froth is collected at the top of the cell. Exposure of the feed to shear, and hence froth formation, is enhanced either by recycling the feed through the outer cyclone into the inner cyclone, or by increasing shear and circulation within the inner cyclone by the use of flow modification assemblies therein.; Residual feed and non-hydrophobic particles are re-covered from the outer cyclone (4) via an outlet (15).

Fig.2.



(12) UK Patent Application (19) GB (11) 2 162 092 A

(43) Application published 29 Jan 1986

(21) Application No 8518103

(22) Date of filing 18 Jul 1985

(30) Priority data

(31) 8418725 (32) 23 Jul 1984 (33) GB

(51) INT CL$^4$
B03D 1/24 B04C 7/00

(52) Domestic classification
B2H 6C 6D X1
B2P 10C2 10D

(56) Documents cited
None

(58) Field of search
B2H
B2P

(71) Applicant
Secretary of State for Trade & Industry (United Kingdom),
1 Victoria Street, London SW1H 0ET

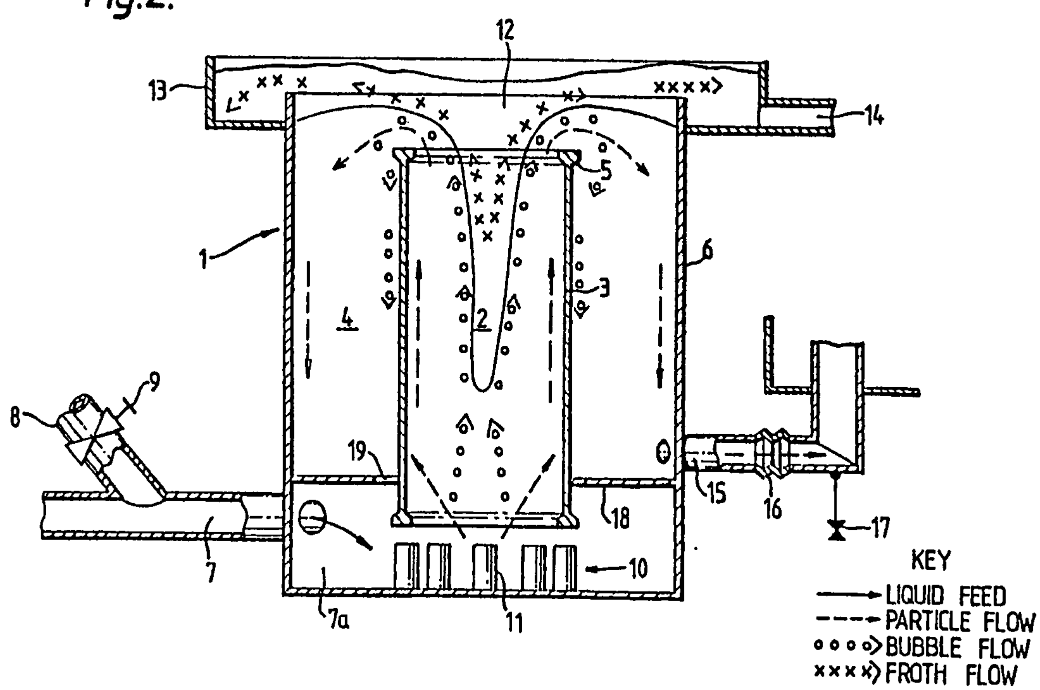
(72) Inventor
Geoffrey Walter Cutting

(74) Agent and/or address for service
R. F. Walker, Procurement Executive, Ministry of Defence, Patent 1A(4), Room 2014 Empress State Building, Lillie Road, London SW6 1TR

# (54) Cyclonic froth flotation cell

(57) A cyclonic froth flotation cell, suitable for use in the separation of minerals comprises concentric inner and outer cyclones (2, 4). A liquid feed containing particles and injected dissolved air is fed tangentially via a conduit (7) into an inlet chamber (7a) below the outer cyclone and in communication with the inner cyclone. On contact with a stator (10), bubbles are generated which form a froth with hydrophobic particles in the feed. The feed passes up through the inner cyclone (2) and the froth is collected at the top of the cell. Exposure of the feed to shear, and hence froth formation, is enhanced either by recycling the feed through the outer cyclone into the inner cyclone, or by increasing shear and circulation within the inner cyclone by the use of flow modification assemblies therein. Residual feed and non-hydrophobic particles are re-covered from the outer cyclone (4) via an outlet (15).

Fig.2.




GB 2 162 092 A

The drawings originally filed were informal ...

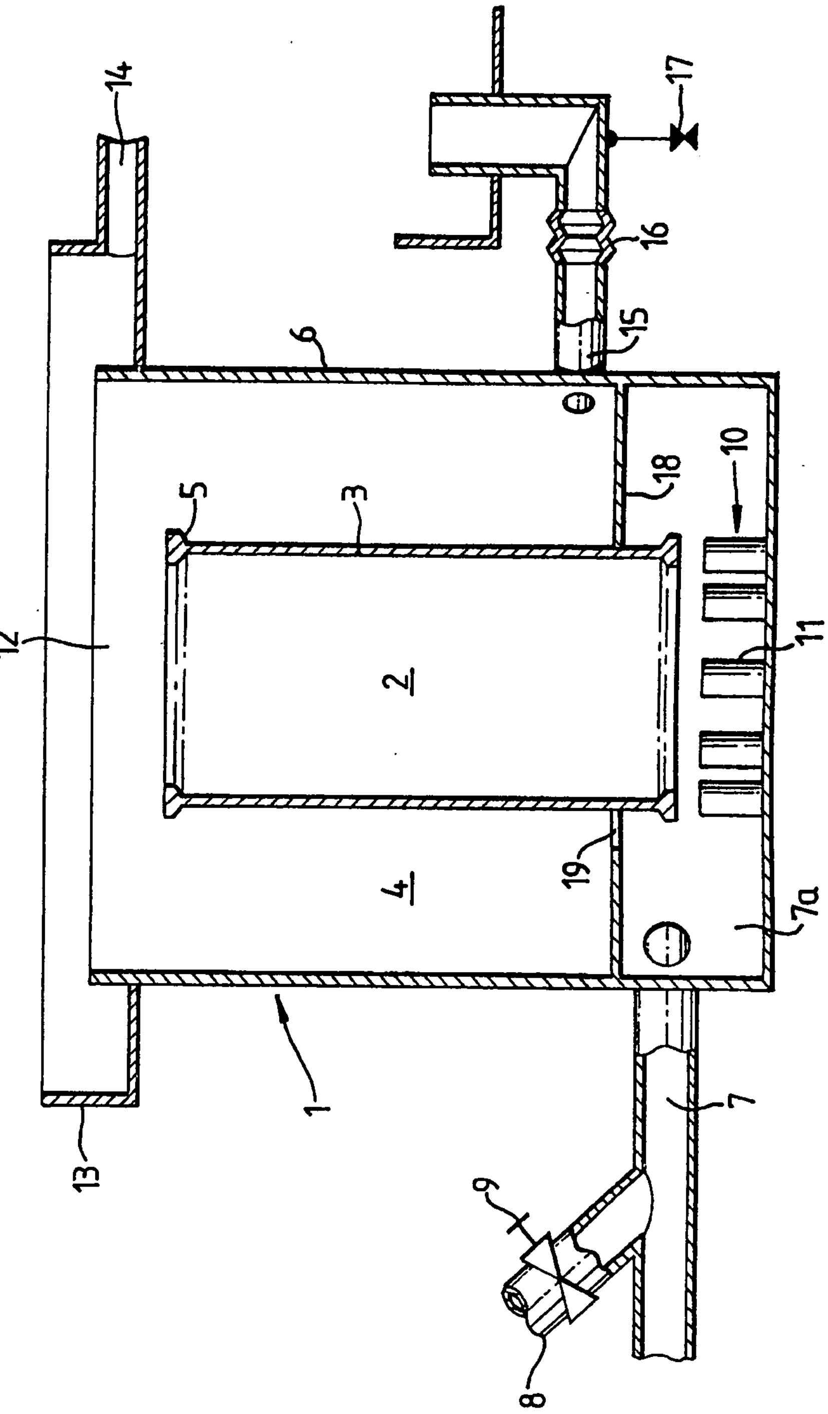



Fig. 1.

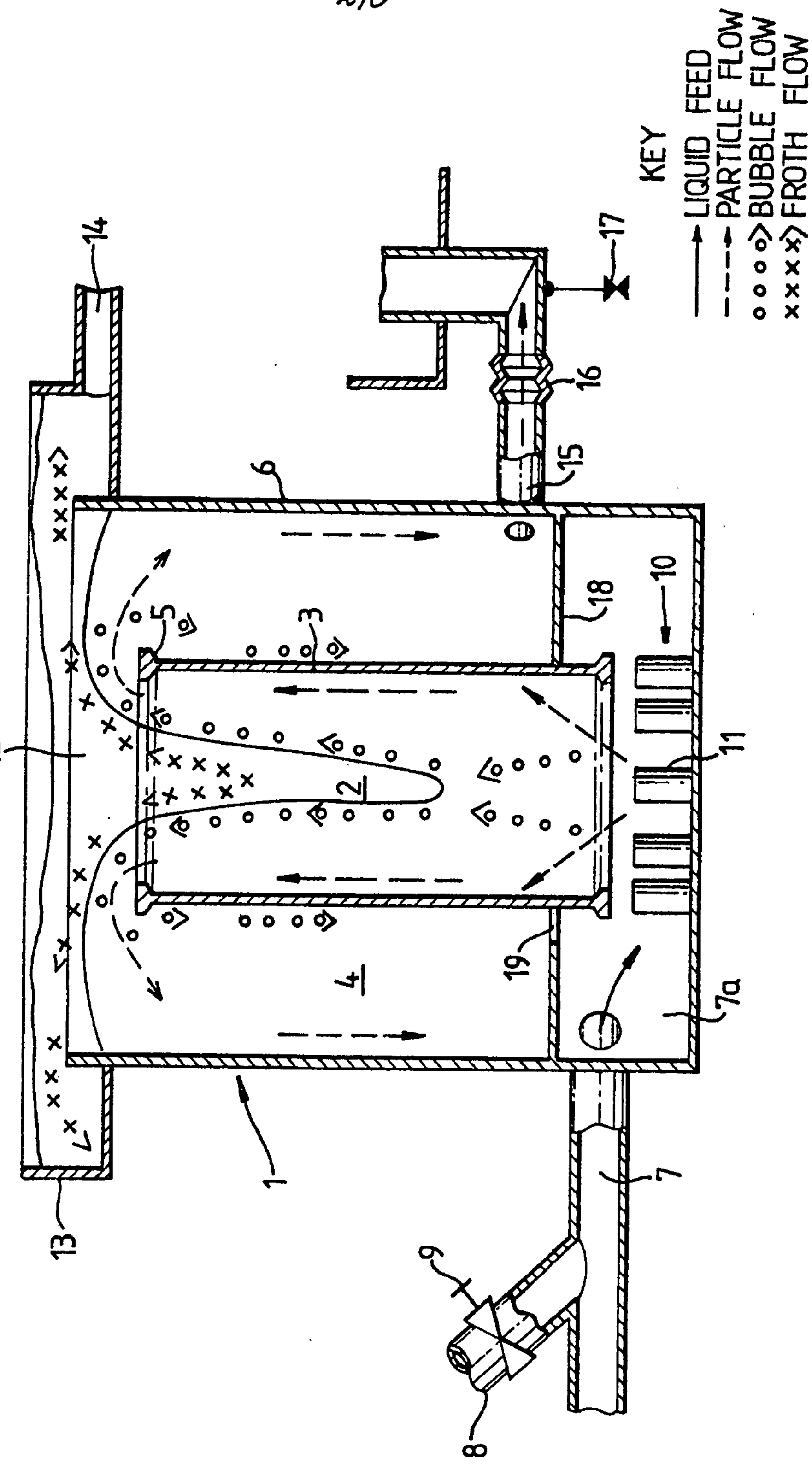

KEY
LIQUID FEED
PARTICLE FLOW
BUBBLE FLOW
FROTH FLOW
1
2
3
4
5
6
7
7a
8
9
10
11
12
13
14
15
16
17
18
19

Fig.2.

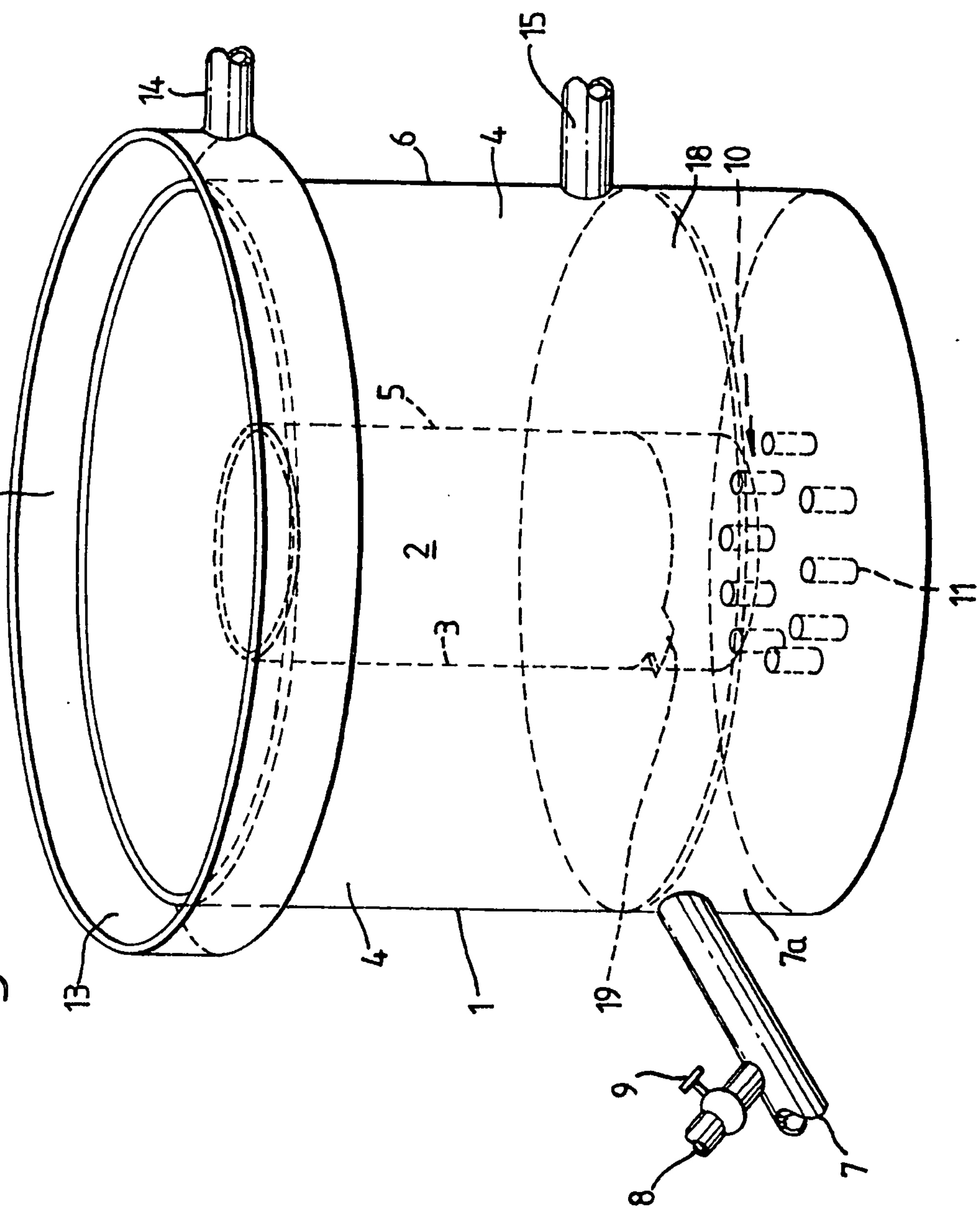



Fig.3

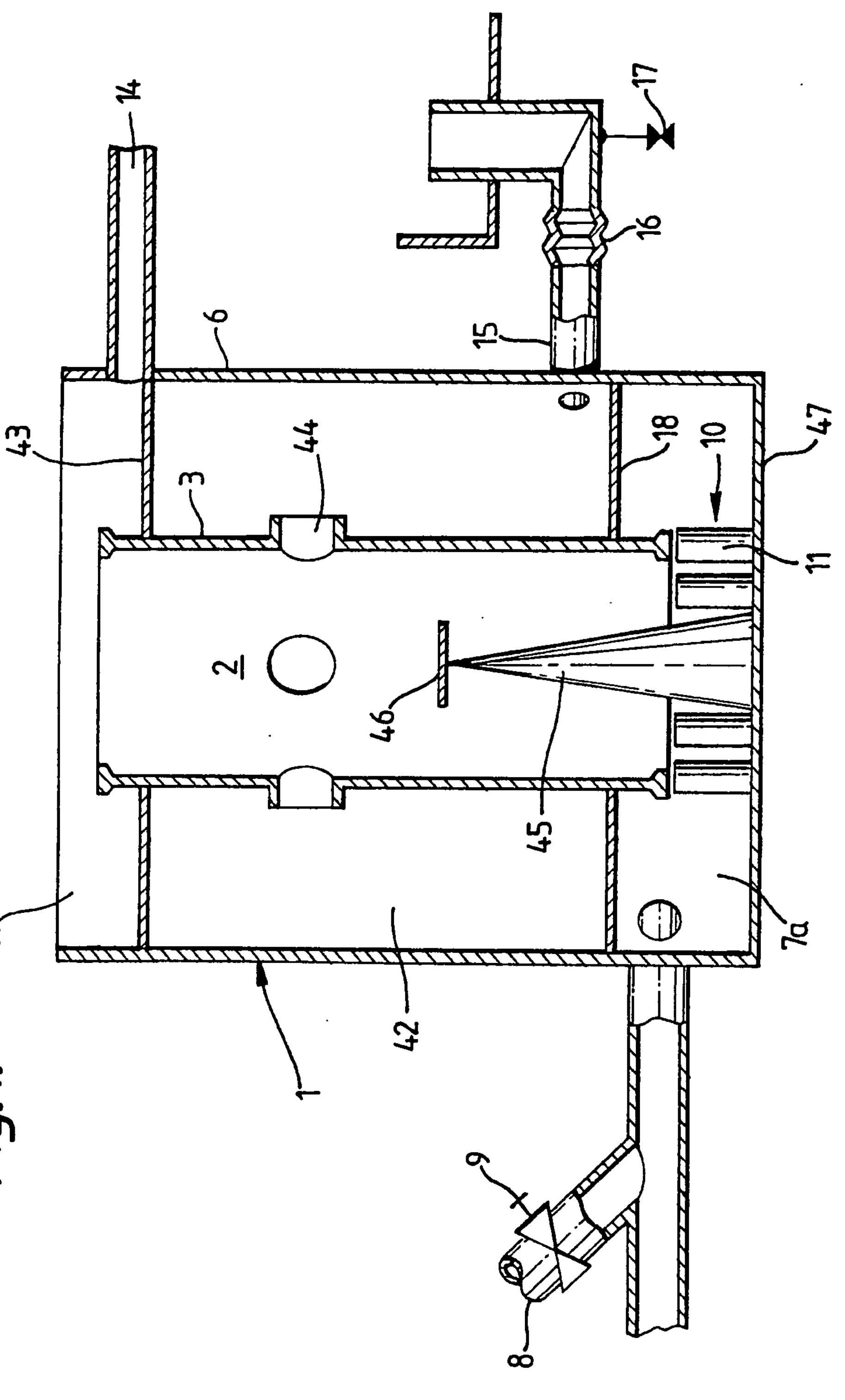
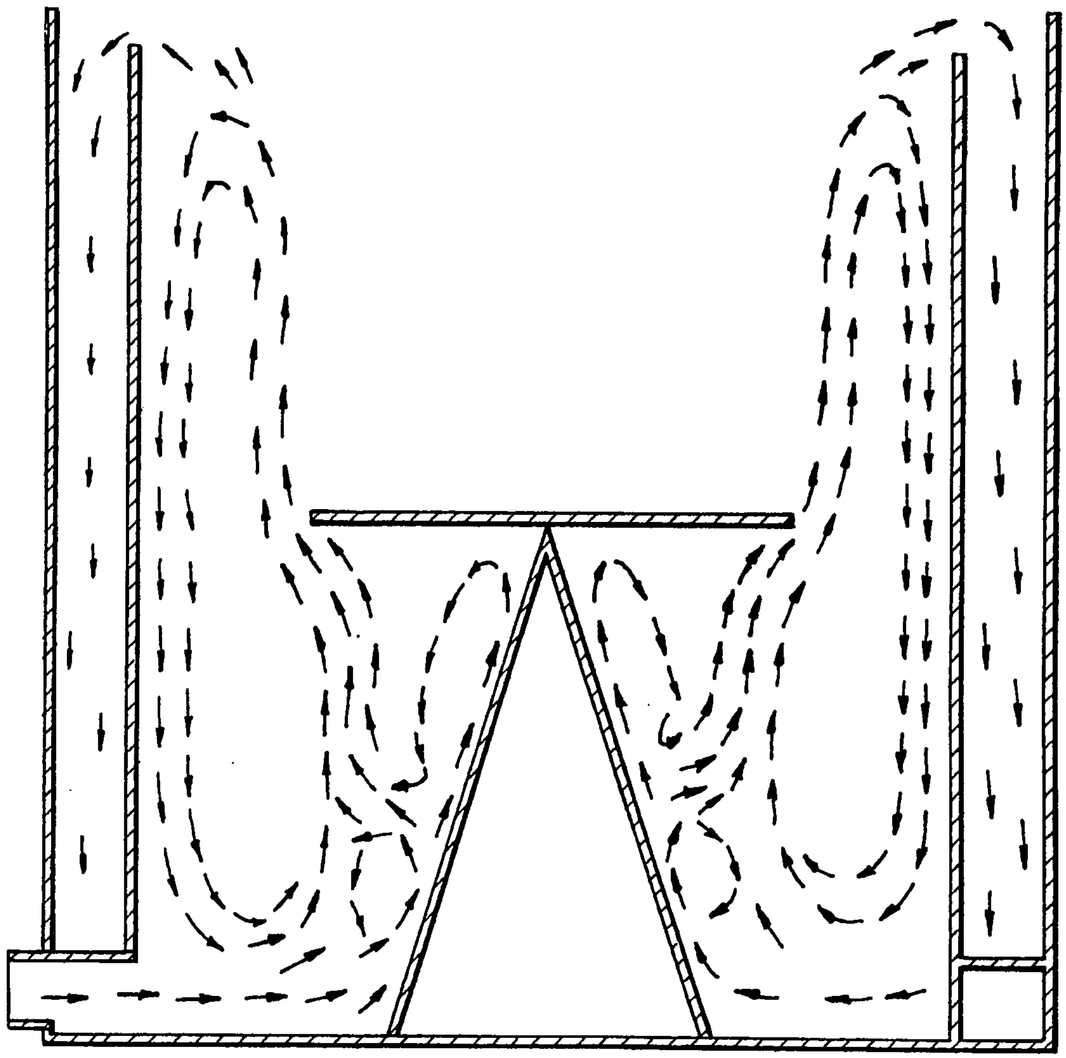



Fig.4.

Fig.5.



SPECIFICATION

**Cyclonic froth flotation cell**

The present invention relates to a cyclonic froth flotation cell and to a process of separation employing the cell.

The froth flotation process finds application on a world-wide basis as the principal means of separating valuable minerals from the unwanted mineral species found in mineral ores. The popularity and ulility of the process stems from amongst other thing, the robustness of the separation cells at present available, the high tonnages that can be treated at comparatively low cost and the particular suitability of the process to those particle sizes at which valuable minerals are generally liberated from host rock. Furthermore the process can treat a very wide range of feedstocks, from those with a very low grade of values (eg < 0.3%) up to those in which the unwanted minerals are merely minor impurities, and can also separate much smaller particle sizes than other separation processes.

Froth flotation relies primarily on the principle that particles with hydrophobic surfaces will be more likely than particles with wet surfaces to attach themselves to bubbles. Thus in a froth flotation process the mineral particles in the liquid feed are first conditioned so that particles of a given type have hydrophobic surfaces, whilst the remainder have hydrophilic surfaces. The liquid feed, containing the conditioned mineral particles, is then introduced into the froth flotation cell. The cell has a motor/impeller system that draws air down a central tube and then disperses the air as bubbles in the body of the liquid feed (pulp phase). The motor/impeller system then mixes the bubbles with the particles suspended in the liquid feed under high shear conditions, whilst maintaining the particles in suspension. The laden bubbles migrate towards the surface of the pulp phase where they form a mineralised froth phase. This (froth) phase is discharged from the cell via one or more walls of the flotation cell, which necessitates a flow through the froth (froth mobility) towards the discharge point. Continuous operation of the cell is maintained by removing the particles with wet surfaces (in the pulp phase) via a residue discharge outlet.

The froth phase not only acts as the means for discharging hydrophobic particles but also contributes to the degree of separation achieved in continuously operated flotation cells. In the froth phase the dominant selection mechanism is drainage of particles back into the pulp phase. Generally the lower the hydrophobic nature of a given particle, the more likely is that particle to drain from the froth to the pulp phase.

Froths are fragile by nature and their structure can easily be disturbed. Such disturbances generally lead to widespread and less selective drainage of particles. One example of just such a disturbance is the froth mobility necessary to discharge from the cell. This mobility introduces shear into the froth, which in turn disturbs the froth structure and induces drainage. Thus in the traditional type of froth flotation cell, the mobility needed to produce a product reduces both the froth selectivity effects and the overall cell efficiency. The larger the cell area, the more adverse will be the effect of the froth mobility.

If, on the other hand, tranquility could be maintained in the froth phase, then, provided this did not adversely effect selectivity or throughput, the overall efficiency of continuously operated flotation cells would be much improved.

A cell which went some way to providing this desired tranquility in the froth phase is described in US Patent No 4,279,743. This patent described an air sparged hydrocyclone having a cylindrical section, surrounded by a gas plenum and a porous wall, and a downwardly oriented conical section. In use, the feed entered the top of the cell via a tangential entry (to impart cyclonic movement), whilst, at the same time, air, under pressure, was forced from the plenum through the porous wall and into the cyclone body. The bubbles entering the cyclone disrupted the boundary layer, thereby freeing entrapped fine particles, and also assisted in carrying hydrophobic particles to cell overflow. When in operation this cell had a froth phase which was compact, short in length and reasonably tranquil.

However, in the present inventor's experience, the cell described in US 4,279,743 has a number of important disadvantages when used as a froth flotation cell. First the cell does not provide either adequate mixing zones or regions of high energy particles/bubble interaction. This will reduce the likelihood of small particles making contact with the bubbles. Second the bubble generation mechanism requires the supply of large volumes of air at relatively high pressures. This is a costly process that will require the installation of (high volume/pressure) air compressors at froth flotation sites. As the mineral industry has little experience in the running of such machines, there is quite likely to be resistance to this requirement.

It is one object of the present invention to provide a froth flotation cyclone that overcomes at least some of the disadvantages of the apparatus described in US 427943 by effecting a better mixing of particles and bubbles and by allowing bubbles to be generated without recourse to a high volume/high pressure air supply.

It is a further object of the present invention to provide a froth flotation cell in which the conditions in the froth phase are tranquil and the drainage of particles back into the pulp phase is therefore highly selective.

Other objects and advantages of the present invention will be apparent from the following detailed description thereof.

According to the present invention there is provided

a cyclonic froth flotation cell comprising an inner cyclone, an outer cyclone surrounding the inner cyclone and in communication with the inner cyclone,

a feed inlet for introducing liquid feed into the feed inlet chamber, said inlet being adapted to

impart cyclonic movement to the liquid feed introduced into the chamber, a stator assembly situated in the path of liquid feed entering the inner cyclone from the feed inlet chamber, said assembly being adapted to generate bubbles in the liquid feed entering the inner cyclone,

a froth discharge outlet, situated at the upper end of the cell for collecting froth flowing outwardly from the inner cyclone,

a residue discharge outlet situated below the froth discharge outlet for collecting residue flowing outwardly from the outer cyclone.

Wherein the cell is constructed so that the liquid feed is recycled within the cell into a region of high turbulence and/or shear.

The present cell may be used in the separation of various particulate materials, especially minerals, by froth flotation. To facilitate this, there is provided in a further aspect of the present invention, a process for the separation of hydrophobic particles from a mixture by froth flotation comprising introducing a mixture containing hydrophobic particles, in the form of a liquid feed, via the feed inlet, into the feed inlet chamber of the cyclonic froth flotation cell of this invention, and

collecting froth bearing the hydrophobic particles at the froth discharge outlet.

The present cell is a compound cyclone having an inner cyclone and a surrounding outer cyclone, these cyclones being in communication with each other. Situated below the outer cyclone and in communication with both the inner and the outer cyclones is a feed inlet chamber. Each of the cyclones and the inlet chamber may be any shape which will allow cyclonic movement of the liquid feed therein. Thus, for example, the inner cyclone may be a downwardly tapering cone, an upwardly tapering cone or, which is preferred, a cylinder. The outer cyclone and the inlet chamber, on the other hand, may be a downwardly tapering annular chamber, an upwardly tapering annular chamber or, which is preferred, a cylinder. In a particularly preferred embodiment of the present cell, the inner cyclone is cylindrical and both the outer cyclone and the feed inlet chamber are annular chambers, of equal inner and outer diameters, surrounding the cylindrical inner cyclone.

Liquid feed is introduced under pressure to the feed inlet chamber, generally by means of a slurry pump. Prior to this introduction, the solid particles within the liquid feed are conditioned, if necessary, so that at least some of the particles within the feed are hydrophobic.

(N.B. There are few naturally hydrophobic minerals, although important substances such as coal, molybdenite, sulphur, talc, pyrophyllite do fall into this category. Most minerals are hydrophilic and as such must acquire their hydrophobic character (for froth flotation purposes) by the adsorption of certain surfactants, known as collectors, that are well known in the froth flotation art).

The liquid feed is preferably further treated at this stage (ie prior to introduction to the inlet chamber) by passing air, from a suitable source, under low pressure, therethrough. This passage of air however is not essential since in an alternative embodiment, the air input may be introduced by inducement at the feed inlet junction. It can be seen from the above that the present cell requires the use of only those facilities, eg slurry pumping, low pressure air supply, slurry handling techniques, that are well known in the minerals separation industry.

The liquid feed enters the feed inlet chamber of the cell through the feed inlet, the inlet being in such a relation with the main body of the cell that the liquid feed entering the cell travels cyclonically within the cell.

This cyclonic movement is preferably effected by having a tangential inlet.

Once inside the cell the feed passes inwards *via* the stator assembly into the inner cyclone. In the present cell the swirling slurry acts in the manner of an impeller in a conventional froth flotation cell and activity in the present stator assembly area is similar to the stator/rotor regime in conventional cells. In the present cell the majority of inlet pressure is dissipated in the stator region. This major pressure drop provides the energy required for mixing and bubble generation and also ensures that there is a considerable interaction between bubbles and particles in this region. The stator assembly may be any system of obstacles that creates turbulence, and thereby generates bubbles, within the liquid feed entering the inner cyclone. In one preferred embodiment of the present cell the stator assembly consists of a circle of vertically orientated cylinders situated under the edge of the inner cyclone. In this case the liquid feed, in order to enter the inner cyclone, must pass between the cylinders, during which passage the turbulence and bubbles required are created. Other suitable forms of stator assembly will however, be apparent to those skilled in the froth flotation art.

On entering the inner cyclone the liquid feed moves upwards, with the loaded bubbles migrating to the vortex at the centre and the particles not attached to bubbles moving to the outer wall (of the inner cyclone). A froth phase bearing hydrophobic particles is developed in the vortex of the inner cyclone. It is a primary advantage of the present cell and process that the froth has some residual "swirl" energy, which creates a froth structure, relatively tranquil in nature, which is moving in a radial direction out of the inner cyclone, over the outer cyclone and towards the outer wall of the compound cyclone cell. By placing the froth discharge outlet at an appropriate position in the upper part of this outer wall the radially moving froth may conveniently be collected.

It can therefore be seen that by imparting rotational movement to the froth phase the problem of froth mobility is essentially overcome by use of the present cell. In view of this and also the generally tranquil nature of the froth formed in the present cell, the drainage from the froth during processes according to this invention will be highly selective. This means, in turn, that a high degree of separation may be achieved using the present cell.

In the cell of the present invention the feed may be

recycled into a region or regions of high turbulence and/or shear, such as that for example around the stator, so as to encourage the attachment of bubbles to hydrophobic particles, in two general ways.

In one alternative, part of the feed from which a first separation of froth and hydrophobic particles has taken place may be recycled through the feed inlet chamber, stator and inner cyclone for a second and subsequent separation. In a second alternative the feed may be recycled into a region or regions of high turbulence and/or shear in the course of a single passage of the feed through the inner cyclone, by encouraging cycling of the feed within the inner cyclone.

In the first alternative the cell may be constructed so that the inner and outer cyclones are in direct communication only at their top, so that the whole of the feed passes through the inner cyclone and over the top of the wall of the inner cyclone into the upper part of the outer cyclone. At this point the froth, containing hydrophobic particles attached to bubbles is collected as previously described.

Unlike the particles attached to bubbles, the particles not attached to bubbles tend to move to the outer wall of the inner cyclone. At the top of the inner cyclone these latter particles move outwards and downwards into the outer cyclone. As they do so they once again come into contact with bubbles in a high shear region, in this case the bubbles left in suspension after the activity in and around the stator assembly. Many of the hydrophobic particles that did not become attached to bubbles in the inner cyclone now become attached to bubbles in the outer cyclone.

It is a furher advanage of this form of construction of the present cell and process that there are two high shear mixing zones, one in the region of the stator assembly and one at the top of the inner and outer cyclones. The presence of the latter zone is especially characteristic of the present compound cyclone.

Once in the outer cyclone the remaining hydrophobic particles are attached to bubbles and move towards the inner wall of the outer cyclone. By contrast the non-hydrophobic particles remain unattached and move towards the outer wall of the outer cyclone.

As the liquid feed moves down the outer cyclone the non-hydrophobic particles leave the cell via a residue discharge outlet situated in the outer wall of the outer cyclone below the froth discharge outlet but above the feed inlet. Generally this residue discharge outlet will be a tangential exit in which back pressure is preferably maintained via a variable feed discharge adapted to control the slurry levels in the cell. When this form of cell is in use it is important that the level of the liquid feed in the outer cyclone should be below the top of the inner cyclone. The variable feed discharge acts as the primary source of control of this liquid feed level.

In contrast to the non-hydrophobic particles in the outer cyclone, the hydrophobic particles attached to bubbles pass through a recycle port in a dividing wall between the outer cyclone and the feed inlet chamber and are thereby reintroduced to the inner cyclone for a second or subsequent separation cycle.

The dividing wall, which is preferably in the form of a plate, is situated below the residue discharge outlet but above and adjacent to the feed inlet. The recycle port, which preferably has an adjustable aperture, is situated within the dividing wall adjacent to the inner cyclone. The wall and the port are so positioned that the partial vacuum produced, when the liquid feed enters from the feed inlet, draws the laden bubbles in the outer cyclone through the port to the inlet chamber and thence on into the inner cyclone. Thus the present cell further increases the efficiency of the froth flotation process by recycling hydrophobic particles that, in a conventional cell, would have been lost in the liquid bearing residue.

In the second alternative recycling within the inner cyclone is encouraged so that the feed is repeatedly returned to a region or regions of higher shear within the inner cyclone during a single passage through the inner cyclone. This may be done and/or enchanced by the introduction of one or more flowstream modification assemblies into the inner cyclone, most effectively along its central axis.

Preferred forms of flowstream modification assemblies are a cone, with its apex uppermost, to increase shear, with a plate at or above the cone apex to induce recirculation of the feed into this region of high shear and that region around the stator. The inventors have found that a flowstream modification assembly in the form of a cone as described above produces enhanced mixing and shear at the base and along the walls of the cone. The addition of a disc above the cone apex enhances these effects but additionally reduces velocity above the disc thus leading to a more tranquil froth phase.

Other forms of flowstream modification assembly as will be familiar to those skilled in the art may be used, depending upon the type of flotation/ separation requirements, and the nature of the desired flow within the inner cyclone. For example a concentric vertical tube may be inserted into the inner cyclone as a flowstream modification assembly.

The type of flow produced within the inner cyclone will also depend upon the properties of the feed, whether or not a flowstream modification assembly is present. For example where a cone is inserted to increase shear, but without a disc, then at low particle contents a substantial central vortex may be produced extending from the top of the inner cyclone to the apex of the cone. The type of flow produced may be ascertained experimentally or by mathematical modelling.

This second alternative wherein recycling within the inner cyclone is caused enables the construction of a form of cell in which the outer cyclone acts only as a means of transferring slurry to the discharge and for controlling the level of feed within the inner cyclone.

In this form of cell the uppermost part of the outer cyclone is merely a froth collection launder, and is

separated from the lower part of the outer cyclone by a dividing wall. The top of the inner cyclone is in direct communication only with this launder.

The lower part of the outer cyclone is in communication with the inner cyclone by an annulus of ports and channelising vanes in the outer wall of the inner cyclone, and is separated from the feed inlet chamber by a dividing wall which in contrast to the first form of cell has no recycle port. A residue discharge outlet is situated in the outer wall of the outer cyclone, which may as above be a tangential exit with means for maintaining back pressure.

In use, the feed in such a cell passes into the inner cyclone and experiences increased exposure to bubbles in a region of high shear. The particles which become attached to bubbles move towards the centre of the inner cyclone and upwards. At the top of the inner cyclone the froth containing these particles passes over the top of the inner cyclone into the froth collection launder, from whence it may be collected as previously described.

The particles not attached to bubbles tend to move towards the outer wall of the inner cyclone, then through the parts in the wall into the outer cyclone, and from thence into the discharge outlet.

In addition to the advantages outlined above the present cell can also treat much larger tonnages per area of floor space used and energy consumed than has been possible heretofore.

The present cyclonic froth flotation cell and froth flotation process will now be described by way of example only with particular reference to

Figure 1 which is a schematic, longitudinal cross sectional view of a cyclonic froth flotation cell according to this invention in which the feed is recycled from the outer cyclone to the inner cyclone.

Figure 2 which is the same view as Figure 1 but showing additionally the direction of particle, bubble and froth flow within the cell.

Figure 3 which is a schematic perspective view of the cyclonic froth flotation cell shown in Figures 1 and 2.

Figure 4 which is a schematic longitudinal cross sectional view of a cyclonic froth flotation cell according to this invention in which flowstream modification assemblies are introduced into the inner cyclone.

Figure 5 which is a simplified cross sectional view of the lower part of the cell of Figure 4 showing the effect of flowstream modification assemblies on flow in the inner cyclone.

Referring to Figures 1, 2 and 3, a cyclonic froth flotation cell according to this invention is shown generally at (1). The cell has a cylindrical inner cyclone (2), with a cylindrical outer wall (3), and an annular outer cyclone (4), surrounding the inner cyclone (2) and having a cylindrical inner (5) and outer (6) wall. A tangential feed inlet (7) is adapted to allow the introduction of liquid feed into the feed inlet chamber (7a) at a tangent and thereby to impart cyclonic movement to the feed within the cell. The feed inlet (7) has a side-arm (8) with a valve (9), through which a controlled quantity of low pressure air may be passed into the liquid feed prior to the introduction of the feed into the cell (1). A stator assembly (10), situated at the bottom of the cell (1), consists of a circle of cylinders (11), positioned underneath the cylindrical outer wall (3) of the inner cyclone (2), through which the liquid feed must pass to reach the inner cyclone (2). The cell (1), which has an open top (12), has a froth discharge outlet, in the form of a circumferential trough (13) surrounding the top of the outer wall (6) of the outer cyclone (4), the trough having an outlet pipe (14) for removing the froth from the cell (1). A tangential residue discharge outlet (15), for removing non-hydrophobic particles from the outer cyclone, has a flexible coupling (16) with the cell (1) and a back pressure control (17) for keeping a constant head of liquid in the cell (1). Finally an annular plate (18), separating the outer cyclone (4) from the feed inlet chamber (7a) is situated above but adjacent to the feed inlet (7). The plate (18) has a recycle port (19), situated adjacent to both the feed inlet (7) and the inner cyclone (2), which is variable in size and allows liquid feed to pass from the outer cyclone (4) to the feed inlet chamber (7a) and thence on into the inner cyclone (2).

In use a liquid feed containing hydrophobic particles and dissolved air is fed by a slurry pump (not shown) into the feed inlet chamber (7a) through the feed inlet (7). The cyclonically moving feed stream then passes downwards and inwards, at which point it meets the stator assembly (10) at the bottom of the cell (1). In this region there is a considerable amount of turbulence which causes bubbles to be generated and a vigorous mixing of the bubbles with the particles. In this way a major proportion of the hydrophobic particles within the feed become attached to bubbles and, as the particles move upwards within the inner cyclone (2), those attached to bubbles tend to migrate to the vortex at the centre, whilst those not attached to bubbles tend to move to the outer wall (3).

At the top of the inner cyclone (2) the particles unattached to bubbles and the unladen bubbles move outwards and then downwards into the outer cyclone (4). In this area the particles and bubbles pass by each other and once again mix vigorously. In this way most of the hydrophobic particles remaining in the feed after passage through the inner cyclone (2) become attached to bubbles and move to the inner wall (5) of the outer cyclone (4), whilst the residual particles move to the outer wall (6). The residual particles leave the cell through the tangential exit (15), whilst the bubbles in the outer cyclone (4), both laden and unladen, pass through the recycle port (19) into the feed inlet chamber (7a) and on into the inner cyclone (2).

(NB. The recycle port 19 is so positioned that a vacuum is produced, by the liquid feed entering the feed inlet chamber (7a) via the feed inlet (7), in the region of the port (19) and this vacuum draws the bubbles in the outer cyclone (4) into the feed inlet chamber (7a)).

Whilst particles unattached to bubbles in the inner cyclone (2) are moving into the outer cyclone (4), those attached to bubbles form a froth at the centre of the inner (2) and at the surface of both (2 and 4)

cyclones. This froth has some residual rotational energy and moves in a radial direction towards the discharge (13) at the top of the outer wall (6) of the outer cyclone (4). The froth leaves the cell through pipe (14).

Referring to Figures 4 and 6, a cyclonic froth flotation cell according to the invention is shown generally at (1). This cell is of generally similar layout to the cell illustrated in Figures 1, 2 and 3. In this embodiment however the uppermost part (41) of the outer cyclone is separated from the lower part (42) of the outer cyclone (4) by a dividing wall (43). This uppermost part (41) of the outer cyclone comprises a froth collection launder from which the outlet pipe (14) leads. The lower part (42) of the outer cyclone is divided from the feed inlet chamber (7a) by a dividing wall (18) which does not have a recycle port.

The open upper end of the inner cyclone (2) communicates with the uppermost part (41) of the outer cyclone, and communication between the inner cyclone (2) and the lower part (42) of the outer cyclone is provided by an annulus of ports (44) in the wall (3) of the inner cyclone.

In the lower part of the inner cyclone (2) there is mounted a flowstream modification assembly in the form of a cone (45) at the apex of which is mounted a disc (46). The base of the cone (45) is mounted on the base (47) of the outer cyclone within and concentric with the circle of cylinders (11) forming the stator assembly (10).

In use a liquid feed containing hydrophobic particles and air is fed into the feed inlet chamber (7a), bubbles are generated as the feed meets the stator assembly (10), and a major proportion of the hydrophobic particles become attached to these bubbles, and the feed moves upward through the inner cyclone (2) as described above.

As the cyclonically moving feed circles around the cone (45) enhanced shear and recirculation occurs around the walls of the cone as shown in the flow diagram of Figure 5. An even greater proportion of the hydrophobic particles become attached to bubbles as a result of the vigorous mixing which occurs in that area.

As the feed moves upward through the inner cyclone (2), the bubbles plus hydrophopbic particles tend to move towards the vortex in the centre of the inner cyclone (2) whereas the particles not attached to bubbles move towards the outer wall (3) of the inner cyclone.

The froth of bubbles plus hydrophobic particles then passes over the top of the inner wall (3) of the inner cyclone (2) into the uppermost part 41 of the outer cyclone, and then under the influence of residual cyclonic motion down the outlet pipe (14) for collection.

The residual particles which have not become attached to bubbles in the inner cyclone move towards the outer wall (3) of the inner cyclone and then through the ports (44) into the lower part of the outer cyclone (42) from whence they are discharged through the discharge outlet (15).

The back pressure control (17) is again used to control the head of liquid within the cell, in this case to prevent residual particles which have not become attached to bubbles from passing over the top of the inner cyclone (2) into the uppermost part of the outer cyclone (41).

CLAIMS

1. A cyclonic froth flotation cell comprising an inner cyclone, an outer cyclone surrounding the inner cyclone and in communication with the inner cyclone,

a feed inlet chamber situated below the outer cyclone and in communication with the inner cyclone,

a feed inlet for introducing liquid feed into the feed inlet chamber, said inlet being adapted to impart cyclonic movement to the liquid feed introduced into the chamber,

a stator assembly situated in the path of the liquid feed entering the inner cyclone from the feed inlet chamber said assembly being adapted to generate bubbles in the liquid feed entering the inner cyclone,

a froth discharge outlet situated at the upper end of the cell for collecting froth flowing outwardly from the inner cyclone

a residue discharge outlet situated below the froth discharge outlet for collecting residue flowing outwardly from the outer cyclone

wherein the cell is constructed so that the liquid feed is recycled within the cell into a region of high turbulence and/or shear.

2. A cell as claimed in claim 1 wherein the cell is constructed so that the liquid feed passes through the inner cyclone and a portion of the liquid feed is then subsequently returned to the inner cyclone through the stator assembly.

3. A cell as claimed in claim 2 wherein the portion of liquid feed is returned to the inner cyclone through the outer cyclone.

4. A cell as claimed in claim 2 or claim 3 wherein the feed inlet is adapted to generate a partial vacuum that draws the returning feed towards the inner cyclone.

5. A cell as claimed in claim 1 wherein the cell is constructed so that the liquid feed is recycled within the inner cyclone so that the feed is repeatedly returned to a region or regions of high shear within the inner cyclone.

6. A cell as claimed in claim 5 wherein the cell is constructed so that recycling within the inner cyclone is caused and/or enhanced by one or more flow stream modification assemblies within the inner cyclone.

7. A cell as claimed in claim 6 wherein at least one of the flowstream modification assemblies serves to increase shear within the feed.

8. A cell as claimed in claim 7 wherein the flowstream modification assembly is in the form of a cone with its apex uppermost.

9. A cell as claimed in claim 6 or 7 wherein the flowstream modification assembly is in the form of a cone with its apex uppermost and with a plate at or above its apex.

10. A cell as claimed in claim 6 wherein the flowstream modification assembly is in the form of a concentric vertical tube within the inner cyclone.

11. A cell as claimed in any one of the preceding claims wherein the stator assembly is in the form of a circle of vertically orientated cylinders situated beneath the inner cyclone.

12. A cell as claimed in any one of the preceding claims substantially as hereinbefore described with reference to the accompanying drawings.

13. A process for the separation of hydrophobic particles from a mixture by froth flotation comprising introducing a mixture containing hydrophobic particles, in the form of a liquid feed, via the feed inlet, into the feed inlet chamber of the cell as claimed in any of the preceding claims and collecting froth bearing the hydrophobic particles at the froth discharge outlet.

Printed for Her Majesty's Stationery Office by Courier Press, Leamington Spa. 1/1986. Demand No. 8817443.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.